

**USARIEM TECHNICAL REPORT**

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**EFFECT OF HYPERCHOLESTREMIA ON CUTANEOUS VASCULAR  
RESPONSES TO EXERCISE IN HEALTHY, EXERCISE-TRAINED,  
HEAT-ACCLIMATED HUMANS**

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**July, 2000**

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13. ABSTRACT (Maximum 200 words) This purpose of this research was to determine whether healthy, exercise-trained, heat-acclimated people with one major risk factor for coronary artery disease (high total cholesterol/high-density lipoprotein cholesterol (TC/HDL-C)) would have different cutaneous vascular responses to exercise in a warm environment compared to people who were of similar age and gender who did not share the risk factor. It was hypothesized that individuals who had an elevated TC/HDL-C would have similar deleterious effects on the cutaneous vasculature as the coronary arteries and aorta as observed in pathological studies. That is, individuals who have a high TC/HDL-C ratio might have less compliant cutaneous vessels and therefore impaired sensible heat loss than individuals who have a low TC/HDL-C ratio. In the current study, we measured cutaneous vascular responses using noninvasive instruments during rest and exercise in a warm environment in individuals with either a high or low TC/HDL-C ratio. Obtaining evidence for impaired heat dissipation was limited by the conservative study design because the volunteers were studied in a moderately hot environment with a moderate humidity rather than a hot environment because half of the study population, by definition, was at risk for coronary artery disease. Subjects in both groups routinely exercised and were heat-acclimated. In a warm environment, moderately heavy exercise done for 30 minutes did not affect thermoregulatory responses in the high TC/HDL-C group as compared to the low TC/HDL-C group. Although cutaneous vascular conductance did not differ between groups, forearm vascular conductance was decreased in the high TC/HDL-C group compared to the low TC/HDL-C group ( $P \leq 0.10$ ). In the high TC/HDL-C group, the mean diastolic pressure during exercise increased by approximately 20% from rest while the mean diastolic pressure decreased by approximately 1% during exercise from rest in the low TC/HDL-C group. The percent change in diastolic blood pressure from rest to exercise was significantly different between groups ( $P \leq 0.001$ ). These two measurements were made noninvasively at the forearm during exercise and are consistent with modified peripheral vasomotor regulation in hypercholesterolemic individuals.					
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Human subjects participated in these studies after giving their free and informed voluntary consent. Investigators adhered to AR 70-25 and USAMRDC Regulation 70-25 on the use of volunteers in research.

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**TECHNICAL REPORT**

**T00-XX**

**Effect Of Hypercholesterolemia On Cutaneous Vascular Responses  
To Exercise In Healthy, Exercise-Trained, Heat-Acclimated Humans**

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## EXECUTIVE SUMMARY

This purpose of this research was to determine whether healthy, exercise-trained, heat-acclimated people with one major risk factor for coronary artery disease (high total cholesterol/high-density lipoprotein cholesterol ratio (TC/HDL-C)) would have different cutaneous vascular responses to exercise in a warm environment compared to people who were of similar age and gender who did not share the risk factor. It was hypothesized that individuals who had an elevated TC/HDL-C would have similar deleterious effects on the cutaneous vasculature as the coronary arteries and aorta as observed in pathological studies. That is, individuals who have a high TC/HDL-C ratio might have less compliant cutaneous vessels and therefore impaired sensible heat loss than individuals who have a low TC/HDL-C ratio. In the current study, we measured cutaneous vascular responses using noninvasive instruments during rest and exercise in a warm environment in individuals with either a high or low TC/HDL-C ratio. Obtaining evidence for impaired heat dissipation was limited by the conservative study design because the volunteers were studied in a moderately hot environment with a moderate humidity rather than a hot environment because half of the study population, by definition, was at risk for coronary artery disease.

Subjects in both groups routinely exercised and were heat-acclimated. In a warm environment, moderately heavy exercise done for 30 minutes did not affect thermoregulatory responses in the high TC/HDL-C group as compared to the low TC/HDL-C group. Although cutaneous vascular conductance did not differ between groups, forearm vascular conductance was decreased in the high TC/HDL-C group compared to the low TC/HDL-C group ( $P \leq 0.10$ ). In the high TC/HDL-C group, the mean diastolic pressure during exercise increased by approximately 20% from rest while the mean diastolic pressure decreased by approximately 1% during exercise from rest in the low TC/HDL-C group. The percent change in diastolic blood pressure from rest to exercise was significantly different between the two groups ( $P \leq 0.001$ ). These two measurements were made noninvasively at the forearm during exercise and are consistent with modified peripheral vasomotor regulation in hypercholesterolemic individuals.

## INTRODUCTION

### Scientific Background

Major risk factors for coronary artery disease include smoking, high total cholesterol/ high-density lipoprotein cholesterol ratio (TC/HDL-C) or other dyslipidemias, hypertension, diabetes, physical inactivity and obesity (Rippe, O'Brien, 1999). Previous studies have documented reduced forearm skin blood flow in smokers (Celermajer et al., 1992), hypercholesterolemic individuals (Casino et al., 1993; Celermajer et al., 1992; Chowienczyk et al., 1992; Drexler et al., 1991), hypertensive men (Calver et al., 1992), and diabetic men (Fortney et al., 1981; Pieper et al., 1991) compared to normal controls. Abnormal endothelium may be the common link among these risk factors as endothelial dysfunction occurs in coronary artery disease (Luscher et al., 1993). One avenue by which endothelial dysfunction occurs in dyslipidemia may be through the inhibition of endothelial-dependent vasodilation by oxidized low-density lipoproteins (Murohara et al., 1994).

Although major risk factors for coronary artery disease were defined epidemiologically specifically for coronary artery pathology, endothelial dysfunction may not be confined to the coronary arteries. It was hypothesized in the current study that chronically elevated TC/HDL-C would have a similar injurious effect on the cutaneous vasculature as on the coronary arteries and aorta as observed in pathological studies (Anonymous 1990; Strong et al., 1999). That is, individuals who have a high TC/HDL-C ratio would have impaired vasomotor regulation of cutaneous vessels than individuals who had a low TC/HDL-C ratio. Endothelial dysfunction in individuals with single or multiple major risk factors for coronary artery disease may contribute to reduced sensible heat flux as heat flux is dependent upon vasomotor regulation of the cutaneous vasculature.

Recently (Strong et al., 1999) it was concluded that atherosclerosis begins in youth (15- to 34-year age span). Fatty streaks and raised lesions were observed in the aortas and frequently in the right coronary arteries upon autopsy in young people who died from external causes. The degree of pathology has been related to serum lipoprotein cholesterol levels in this young population (Anonymous, 1990). Vascular evidence of coronary artery disease or atherosclerosis is usually not obtained in healthy

young people. Only recently, carotid artery flow assessment by ultrasound has become available for hospital testing. Increased carotid thickness and coronary calcification has been detected in relatively young people and correlated to elevated LDL concentration (Davis et al., 1999). Another recent finding (Brett et al., 2000) indicates that total cholesterol concentration and insulin resistance are correlated with change in diastolic blood pressure during mild exercise in healthy men (age 18 to 66 years). That is, diastolic blood pressure increased more during mild exercise in men with TC in the highest quartile of the population studied, while it decreased during exercise in men with TC in the lowest quartile of the population. Taken together, these new findings indicate that blood pressure and vasomotor regulation may be affected in healthy, hypercholesterolemic individuals during more intense exercise.

#### Purpose

The purpose of this research study was to examine vascular responses to exercise in individuals with at least one risk factor for coronary artery disease compared to individuals who did not share that particular risk. It was hypothesized that individuals who had an elevated TC/HDL-C would have less compliant cutaneous vessels than individuals who had low TC/HDL-C. The current research was done to functionally test for symptoms of atherogenesis in healthy people by observing the responses of the cutaneous vasculature to exercise. Individuals who have a high TC/HDL-C ratio may exhibit some functional impairment in the cutaneous vasculature during exercise that is associated with increased arterial resistance during exercise. If there is functional impairment of the cutaneous vasculature during exercise, it might be expected that these individuals have a greater propensity for heat illness or heat injury. Sensible heat dissipation may be impaired in this risk group as sensible heat flux is dependent upon vasomotor regulation of the cutaneous vasculature. As a safety precaution, the volunteers were studied in a moderately hot environment with moderate humidity even though impaired heat dissipation was hypothesized for the hypercholesterolemia groups. This safety precaution had the effect of minimizing our ability to resolve thermoregulatory differences between the risk factor group and the control group.

### Military Relevance

Descriptions of vascular pathology in young people who have a high TC/HDL-C ratio (Anonymous, 1990) raised the question of whether active-duty soldiers with high TC/HDL-C are at greater propensity for heat illness or injury due to functional impairment of the cutaneous vasculature. If this is the case, there might be even greater potential for heat injury in soldiers with this risk factor.

Beginning in 1991, the U.S. Army implemented a Health Promotion Program in which all active duty, National Guard and Reserve Army personnel were required to undergo a Health Risk Appraisal (HRA) during each medical exam (every 5-years). At that time, Burke (1991) estimated that ~25% of U.S. Army aviators had hypercholesterolemic levels that would at least require dietary therapy as treatment according to the guidelines of National Cholesterol Education Program Expert Panel. As of 1995 (Rao, 1999), the total cholesterol levels of 30% of the men and 24% of the women for the total HRA population were at or greater than 200 mg/dl. In light of the major risk of coronary artery disease associated with hypercholesterolemia and the theory that endothelial dysfunction may be a component of this risk, we reasoned that hypercholesterolemia might also prove to be a risk for heat injury during exercise. Although this wasn't the case for the conditions of the present study, we did gather additional evidence that hypercholesterolemia does adversely affect vasomotor regulation during exercise.

## **METHODS**

### Test Subjects

Eight people (6 men and 2 women) volunteered to do the study after they were formally briefed on the study design and risks. All volunteers exercised habitually and were acclimated to heat. None of the volunteers were medicated and use of aspirin and ibuprofen was prohibited for 10 days prior to an experiment. Volunteers learned the procedures used in the experiments and were also familiarized with the investigators by attending up to five procedural training sessions. Female volunteers were studied in the early follicular phase of the menstrual cycle. Table 1 shows the subject characteristics.

**Table 1. Subject Characteristics.**

Gender	TC/HDL-C	Age (y)	Height (cm)	Weight (kg)	Peak Aerobic Power (L/min)	(ml/min/kg)
<b>Low TC/HDL-C</b>						
Male	3.94	20	193.4	103	3.662	35.55
Male	3.48	43	177.8	81.8	3.358	41.05
Female	3.08	41	173	70.7	2.367	33.48
Male	2.92	22	185	78.1	4.195	53.71
<b>Mean</b>	<b>3.36</b>	<b>31.5</b>	<b>182.3</b>	<b>83.4</b>	<b>3.396</b>	<b>40.95</b>
S.D.	(0.46)	(12.2)	(8.9)	(13.9)	(0.77)	(9.09)
<b>High TC/HDL-C</b>						
Male	4.40	19	169	61	2.888	47.34
Male	5.42	28	190.5	88.6	4.566	51.54
Female	4.18	46	157.5	58.2	1.780	30.58
Male	6.17	20	188	86	3.466	40.30
<b>Mean</b>	<b>5.08</b>	<b>28.3</b>	<b>176.3</b>	<b>73.5</b>	<b>3.175</b>	<b>42.44</b>
S.D.	(0.98)	(12.5)	(15.8)	(16.1)	(0.77)	(9.17)
P	<b>0.02</b>	ns	ns	ns	ns	ns

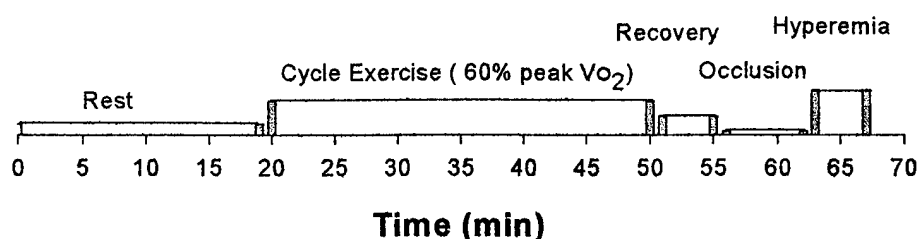
**Experimental Design**

Each volunteer did an exercise experiment on each of three separate days with at least one day between experiments. The ambient dry bulb temperature was 30°C and the ambient dew-point temperature was 12°C.

**Test Procedures**

Test subjects were nonsmokers. The test subjects fasted overnight, and refrained from drinking alcohol 24 h prior to the experiment. Water ingestion was permitted until the experiment started. Before the experiment, a 5- ml venous blood sample was drawn for determination of triglycerides, total cholesterol and HDL cholesterol (Sigma Diagnostics). Laboratory accreditation for the cholesterol assay was obtained through Northwest Lipid Research Laboratories (Seattle, WA). The time of the experiment was approximately the same time of day for each test subject for all experiments (starting between 0700-0730 h)

**Figure 1**



to control for circadian differences in skin blood flow and thermoregulation (Stephenson and Kolka, 1995; Stephenson et al., 1984)

### Exercise Test

The test subjects entered the environmental test chamber dressed in shorts, singlet, shoes, socks and underwear. Male subjects often chose not to wear the singlet, but the clothing chosen was the same for all experiments. Electrocardiographic electrodes and leads were attached to the torso. The subject swallowed a thermistor or thermocouple encapsulated in waterproof insulation for the measurement of esophageal temperature ( $T_{es}$ ). The esophageal temperature probe was inserted to a depth of about 25% of the individual's height. The volunteer was weighed and then sat on the chair of the modified cycle ergometer. Thermocouples (copper-constantan) were attached to the skin at eight sites. Venous occlusion plethysmography (Hokansen, Bellevue, WA) was used to measure forearm blood flow (FBF) (Doherty et al., 1993; Whitney, 1953) and laser-Doppler velocimetry (Vasamedics, St. Paul, MN) was used to measure skin blood flow (SkBF) (Johnson et al., 1984) on the forearm and chest. Local skin sweating rate was measured on the forearm in a contralateral position to the laser-Doppler probe. An automatic blood pressure monitor (Datascop, Inc., Paramus NJ) was used to determine systolic and diastolic blood pressure.

Figure 1 is a timeline showing the sequence of events for each experiment. After all instruments were attached to the subject, a 20-min control period was started. Esophageal and skin temperatures, forearm blood flow, skin blood flow, and local sweating rate were measured every 0.5 min, and blood pressure and heart rate were measured every 5 min. The subject exercised for 30 min at 60% peak VO<sub>2</sub> during which time the temperature, blood flow and heart rate measurements were made at the same

time intervals as during rest. Blood pressure was measured every 2.5 min. Exercise ended after 30 min and the volunteer recovered for five minutes. Arterial occlusion was then initiated. Occlusion lasted 7 min except for two subjects who could tolerate only 5 min (S2 and S3). After occlusive pressure was released, skin blood flow was measured to gauge the hyperemic response. After the experiment, the subject was weighed.

#### Data Calculations & Analyses.

To evaluate whether there was any difference in vasomotor regulation between the low and high TC/HDL-C groups, forearm vascular conductance (FVC) and cutaneous vascular conductance (CVC) were calculated by the formulae:

$$\begin{aligned} \text{FVC (ml} \cdot 100 \text{ ml}^{-1} \cdot \text{min}^{-1} \cdot \text{Torr}^{-1}) &= \text{FBF (ml} \cdot 100 \text{ ml}^{-1} \cdot \text{min}^{-1}) \cdot \text{MAP}^{-1} \text{ (Torr)} \cdot 100 \\ \text{CVC (ml} \cdot 100 \text{ ml}^{-1} \cdot \text{min}^{-1} \cdot \text{Torr}^{-1}) &= \text{SkBF (ml} \cdot 100 \text{ ml}^{-1} \cdot \text{min}^{-1}) \cdot \text{MAP}^{-1} \text{ (Torr)} \cdot 100 \end{aligned}$$

The results for the three exercise tests were averaged to give a mean response for each physiologic measure in each subject. Physiologic responses were analyzed by two-way analysis of variance (Group X Time) between low and high TC/HDL-C. When there was a significant interaction between group and time, the data set was segmented into rest, exercise, and recovery periods.

T tests were done to compare data between groups when time was not an included factor. Specifically, unpaired T tests were done to compare subject characteristics. Unpaired T tests were done to compare change in esophageal temperature at the initiation of exercise, duration of change in esophageal temperature at the initiation of exercise, and cutaneous vascular conductance during the hyperemic response.

Given the small number of subjects in each group,  $\alpha = 0.10$  was chosen. Thus, a probability of less than 10% was judged to be a significant difference between groups. By choosing this probability level, a Type I error may be made such that the null hypothesis is rejected when it, in fact, is true in 10% of the cases. Each subject did the exercise test three times. These data were averaged to reduce the error variance for each subject and used in the statistical analyses. By using the mean data, the possibility of a Type II error was reduced which justified the  $\alpha$ -level chosen.

## RESULTS AND DISCUSSION

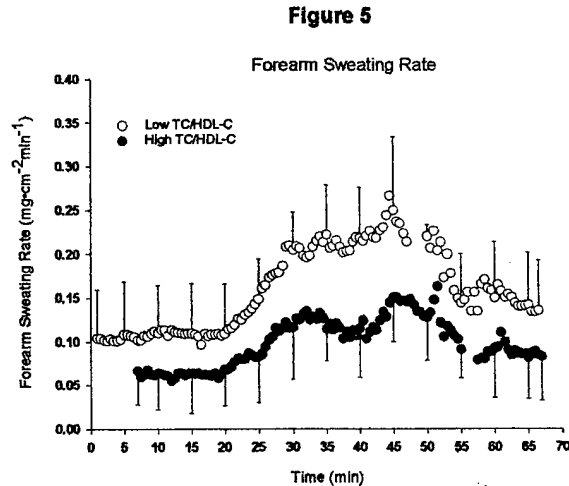
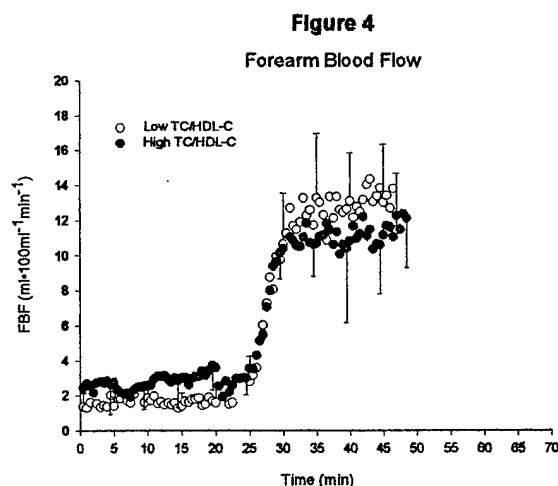
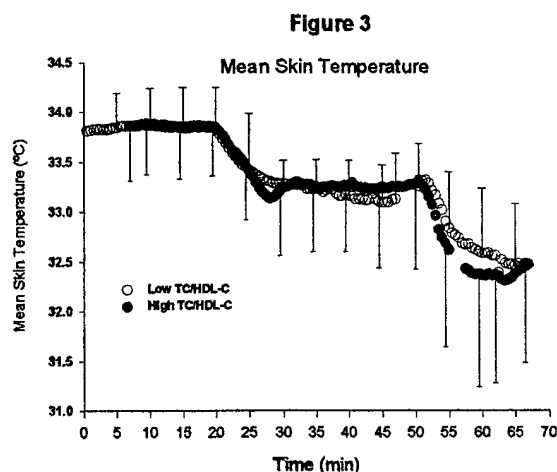
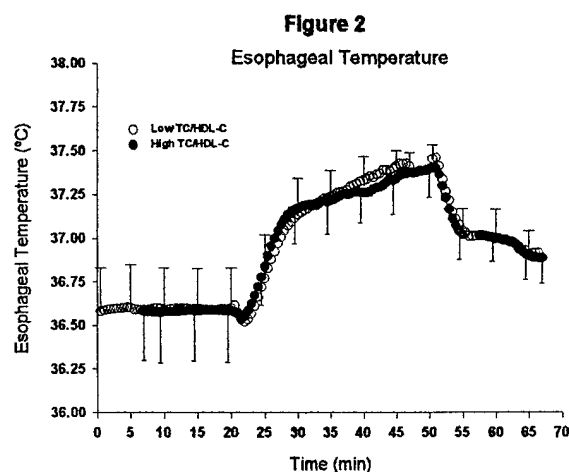
The U.S. Army implemented a Health Promotion Program in 1991 in which all Active Duty, National Guard and Reserve Army personnel were required to undergo a Health Risk Appraisal during each medical exam. The Health Promotion Program is one way by which the Army promotes personnel lifestyle changes to reduce the individual soldier's cholesterol level below 200 mg/dl. When the Health Promotion Program was instituted, Burke (Burke, 1991) estimated that ~25% of U.S. Army aviators had hypercholesterolemic levels that would at least require dietary therapy if the guidelines of National Cholesterol Education Program Expert Panel were used to decide treatment.

Despite the major risk of coronary artery disease associated with hypercholesterolemia, only 35% of Americans eligible for diet or drug intervention actually are treated (Gotto, 1999). Based on the low incidence of treatment, apparently the question still remains in the medical community whether there is a treatment benefit for healthy, physically fit people with hypercholesterolemia. Yet, the benefit of lipid management has been recently reported (Gotto, 1999). Because endothelial dysfunction may be a component of the dyslipidemic risk, we reasoned that hypercholesterolemia might also prove to be a risk for heat injury during exercise as endothelial dysfunction may be expected to adversely affect vasomotor regulation. In the present study with its mild heat stress, no thermoregulatory evidence that high TC/HDL-C might predispose to heat injury was found. There was, however, evidence that high TC/HDL-C affected vasomotor regulation during exercise.



## Thermal Responses

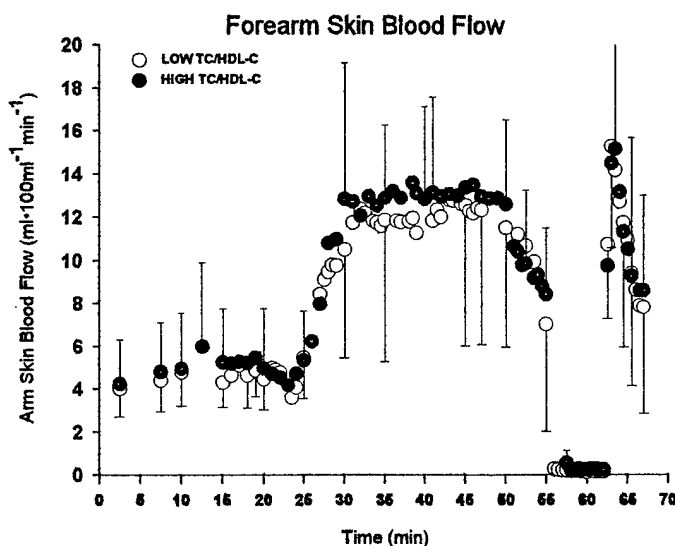
There were no significant differences between the low and high TC/HDL-C groups in esophageal and mean skin temperature responses (Figures 2 and 3). In the two groups esophageal and mean skin temperature actually tracked similarly during the experiment. It should be noted that the vasoconstrictor response to exercise was also similar between groups. This is an important observation because there is a reduced vasoconstrictor response in smokers compared to nonsmokers (Stephenson et al., 2000).



Figures 4 & 5 show forearm blood flow and sweating data. There were no differences between the low and high TC/HDL-C group in either response. Even though sweating rate appears to be lower in the high TC/HDL-C group, the conditions of the experiment are such that there was hardly a requirement for sweating as radiative and convective heat dissipation together were effective. Forearm skin blood flow as measured

by laser-Doppler was not different between the low and high TC/HDL-C groups (Figure 6). The low sweating rate as well as the core and skin temperature responses indicate that the experimental conditions of the current study were too conservative to tease out any thermoregulatory differences between groups.

Figure 6



### Cardiovascular Responses

Systolic blood pressure was not different between the low and high TC/HDL-C groups. In scrutinizing the data for symptoms of early atherogenesis, both diastolic blood pressure and pulse pressure were compared between the two groups. Neither index was significantly different (Figures 7 & 8).

Figure 7

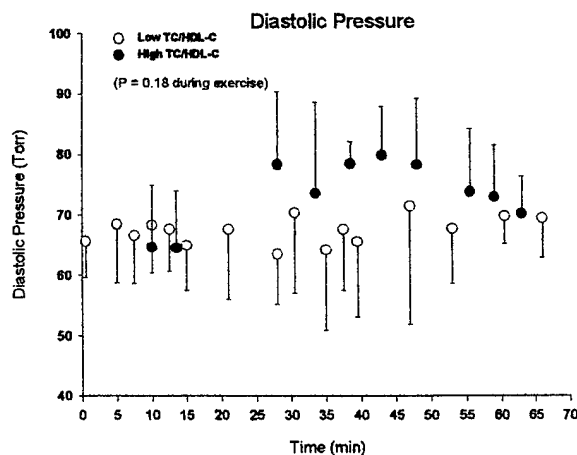
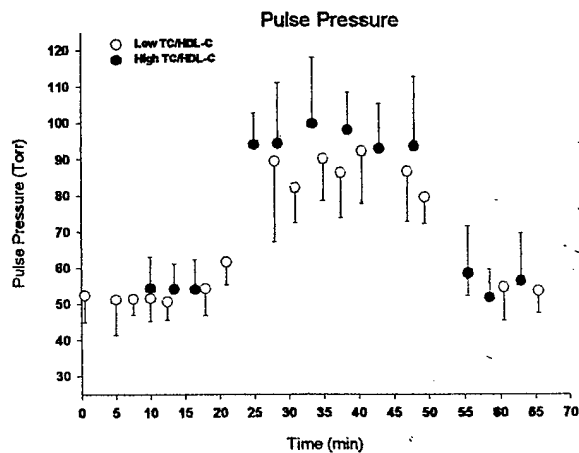


Figure 8



When the change in diastolic blood pressure induced by exercise was calculated, there was a greater increase in diastolic blood pressure during exercise in the high TC/HDL-C group compared to the low high TC/HDL-C group (Figure 9). Table 2 shows the percentage change in diastolic blood pressure during exercise when calculated from the mean diastolic blood pressure at rest for each individual. The grand mean (for all subjects at four exercise times) change in diastolic pressure during exercise from rest for the high TC/HDL-C group was 20.1 ( $\pm 4.3$ )%. In contrast, the grand mean change in diastolic blood pressure during exercise was only -1.3 ( $\pm 2.8$ )% in the low TC/HDL-C group. The % change in diastolic blood pressure during exercise was significantly different between groups ( $P \leq 0.001$ ). Heart rate was not different between groups showing that the two groups were working at similar exercise intensities (Figure 10).

Table 2. Change in Diastolic Blood Pressure from Rest to Exercise (%).

Low TC/HDL-C (3.4 $\pm$ 0.5)					High TC/HDL-C (5.1 $\pm$ 1.0)				
Subject	~Exercise Time				Subject	~Exercise Time			
	8 min	15 min	18 min	27 min		8 min	15 min	18 min	27 min
2	-12.8	10.5	5.6	5.6	3	16.7	-2.5	41.4	21.6
4	-2.4	-14.6	2.4	8.2	12	17.1	14.5	9.3	20.1
7	6.2	-2.3	1.7	-6.3	6	24.7	31.4	27.0	32.5
15	-6.6	-7.8	-2.4	-6.6	11	27.7	11.8	15.3	12.8
<b>Mean</b>	<b>-3.9</b>	<b>-3.6</b>	<b>1.8</b>	<b>0.2</b>	<b>Mean</b>	<b>21.6</b>	<b>13.8</b>	<b>23.3</b>	<b>21.8</b>
<b>SD</b>	<b>8.0</b>	<b>10.6</b>	<b>3.3</b>	<b>7.8</b>	<b>SD</b>	<b>5.5</b>	<b>13.9</b>	<b>14.2</b>	<b>8.1</b>

Figure 9

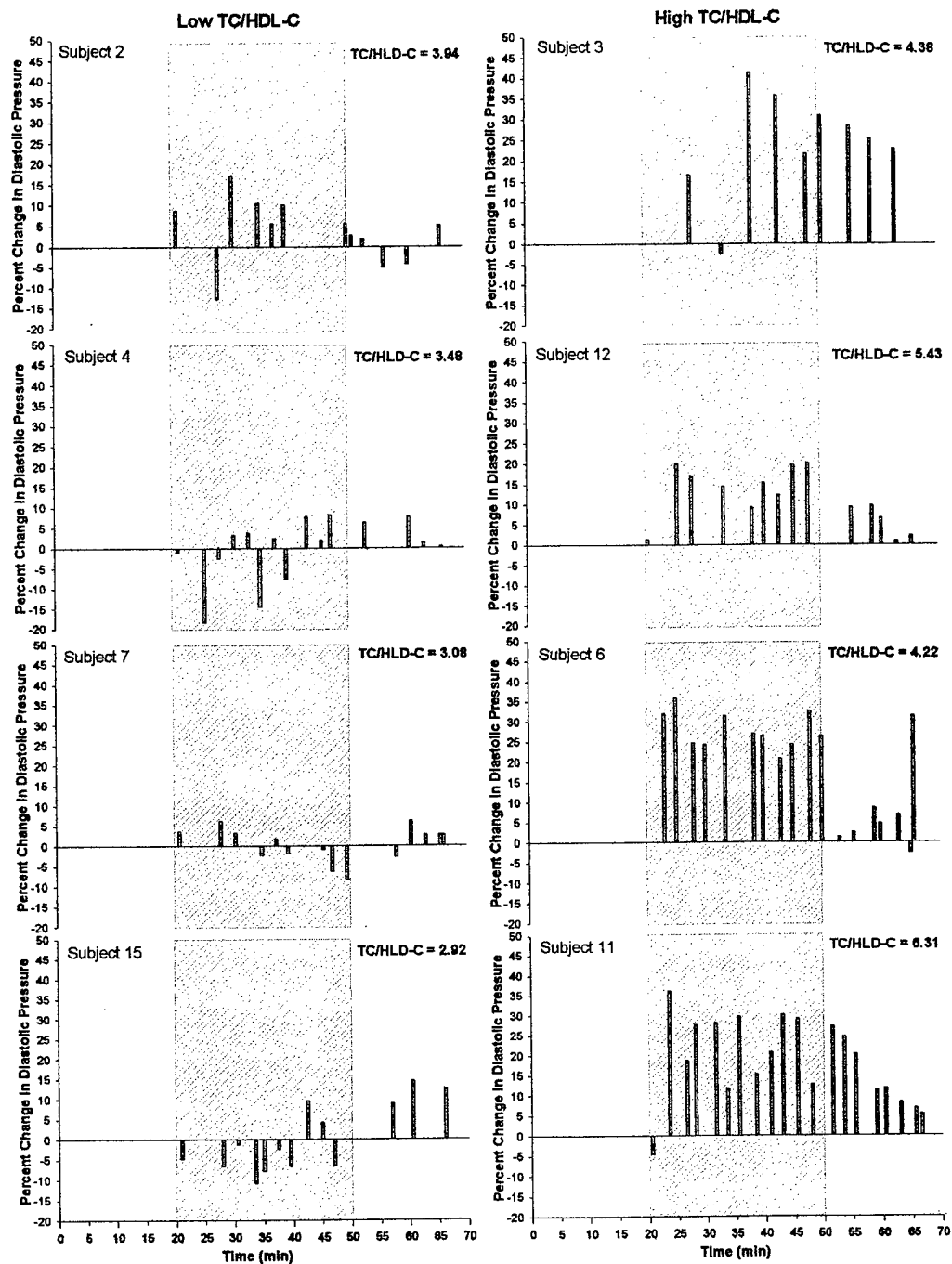
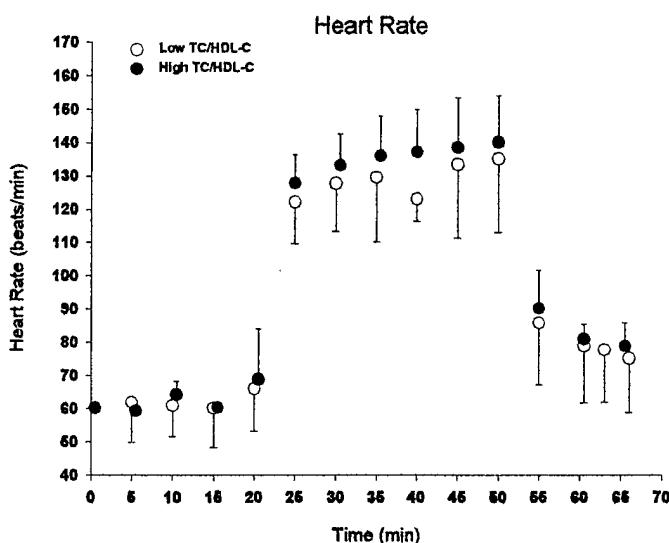


Figure 10



There were no differences between groups in cutaneous vascular conductance (Figure 11). Figure 12 shows that FVC was reduced during exercise in the high TC/HDL-C group compared to the low TC/HDL-C group ( $p=0.098$ ). These two observations taken together may indicate that the surface cutaneous vessels are responding similarly in the two groups during exercise, but the group responses to exercise differ in the deeper resistance vessels which would be measured by FVC.

Figure 11

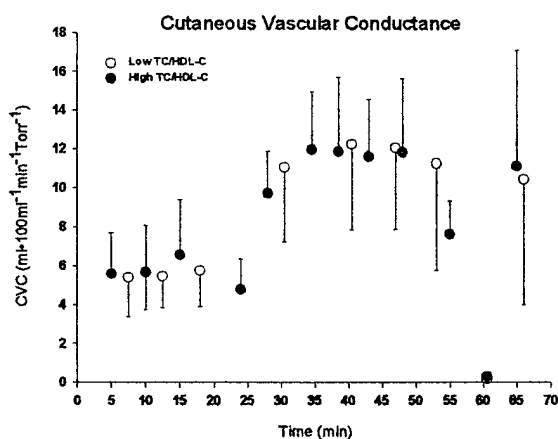
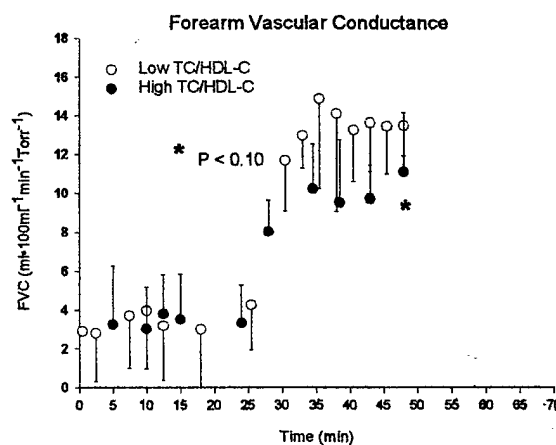


Figure 12



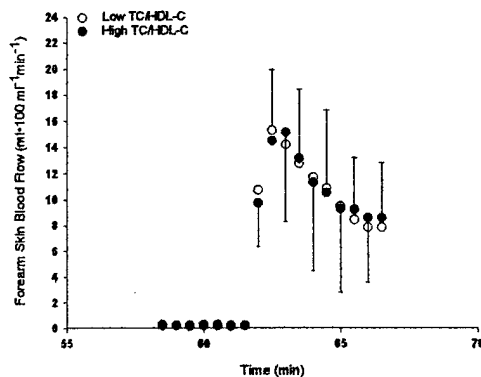
### Hyperemic Responses

Figure 13 shows the reactive hyperemic response to arterial occlusion done between minutes 55-62 of the experiment. There was no difference in the hyperemic response between the low and high TC/HDL-C groups. This measurement is also

made on surface cutaneous vessels and therefore may indicate that hypercholesterolemia does not affect capillary and arteriolar vessels at the skin surface because laser-Doppler flowmetry measurements are made at a depth of 1 mm from the skin surface.

Figure 13

Hyperemic Response



### Perspectives

There was no indication that hypercholesterolemia compromised thermal responses to a 30-min exercise bout in a warm environment, but the finding that the percentage change in diastolic blood pressure increased during exercise from resting values in the high TC/HDL-C group and not in the low TC/HDL-C group is significant because it indicates reduced vascular reactivity in the high TC/HDL-C group. This finding is relevant to the military because reduced vascular reactivity would be expected to have a greater impact on thermoregulation when the hypercholesterolemic individual was exposed to uncompensable heat stress while exercising. These conditions would occur during military operations when exercise is done in hot, humid environments or when soldiers are exercising in chemical protective clothing. According to Rao (1995), 30% of military men and 24% of military women have TC  $\geq$  200 mg/dl. All soldiers with TC  $\geq$  200 mg/dl do not necessarily have a high TC/HDL-C ratio, but one would expect that there is a greater likelihood of a high ratio in individuals with high total cholesterol. It might also be expected that older soldiers would be more likely to have a high

TC/HDL-C ratio, but the current research shows that vascular reactivity is reduced in young men (< 30 years old; Tables 1 and 2) too.

The finding that the percentage change in diastolic blood pressure increased during exercise from resting values in the high TC/HDL-C group and not in the low TC/HDL-C may be used in several ways. First, the magnitude of the increase in diastolic blood pressure during exercise might be developed as a method to distinguish compromised vasomotor regulation in the cutaneous vasculature. Further research would be required to fully resolve the threshold for percentage change in diastolic blood pressure that indicates compromised vasomotor regulation. Once the threshold is defined however, these measurements could be made at many fitness clinics that are staffed with exercise physiologists. The benefit from such an endeavor would be to assess the magnitude of the change in diastolic blood pressure with exercise for each hypercholesterolemic individual so that necessity for treatment and type of therapy warranted might be determined subsequently by the individual's physician. The U.S. Army Health Promotion Program has set a standard of reducing the mean TC levels to at or below 200 mg/dl in active duty personnel. A demonstration to the hypercholesterolemic individual of the personal consequence of a high TC/HDL-C ratio on peripheral vasomotor regulation might motivate him or her to initiate dietary intervention. If the individual chooses not to initiate dietary therapy, the magnitude of the % change in diastolic blood pressure with exercise might be used to determine whether the individual reached the threshold change in diastolic pressure with exercise that would require pharmaceutical treatment for hypercholesterolemia. Finally, the efficacy of treatment could be determined by a follow-up test to determine the percentage change in diastolic blood pressure with exercise. That is, if treatment reduces TC/HDL-C, does the exercise-induced increase in diastolic pressure also diminish?

## CONCLUSIONS

Subjects in both groups routinely exercised and were heat-acclimated. Exercise and heat acclimation each improve the cutaneous vasodilatory response to exercise in humans. In a warm environment, thermoregulatory responses were not different between the high TC/HDL-C group and the low TC/HDL-C group during moderately heavy exercise done for 30 minutes. The percent change in diastolic pressure induced by exercise was 20% in the high TC/HDL-C group and -1% in the low TC/HDL-C group ( $P \leq 0.001$ ). Although cutaneous vascular conductance did not differ between groups, forearm vascular conductance was decreased in the high TC/HDL-C group compared to the low TC/HDL-C group ( $P \leq 0.10$ ). These observations are consistent with the interpretation that hypercholesterolemia in healthy, physically fit, heat acclimated people may be associated with compromised peripheral arterial resistance.

The noninvasive experimental procedures used in this research protocol can be used to functionally test for compromised vasomotor regulation or impaired vascular reactivity in healthy, physically fit people.



## RECOMMENDATIONS

It is recommended that more research be done to determine whether hypercholesterolemia is associated with reduced ability to dissipate heat in hotter, humid environments during more sustained work.

Development of a screening test to determine whether moderately heavy exercise in a warm environment increases diastolic blood pressure significantly in a hypercholesterolemic individual is also recommended. This screening test might be used both to aid in determination of the type of treatment, dietary, pharmaceutical or both together. It could also be repeated to determine whether effective treatment results in a reduction in exercise-induced increased diastolic blood pressure.

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